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jc713 U.S. PTO
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UTILITY PATENT APPLICATION TRANSMITTAL

(Only for new nonprovisional applications under 37 CFR 1.53(b))

Attorney Docket No.	042390.P7490
First Inventor or Application Identifier	Tinku Acharya
Title	METHOD OF CONVERTING A SUB-SAMPLED COLOR IMAGE
Express Mail Label No.	EL034432552US

jc530 U.S. PTO
09/461068
12/14/99

APPLICATION ELEMENTS
See MPEP chapter 600 concerning utility patent application contents

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Washington, DC 20231

1. ☒ Fee Transmittal Form
(Submit an original, and a duplicate for fee processing)
2. ☒ Specification [Total Pages 18]
(preferred arrangement set forth below)
   - Descriptive title of the Invention
   - Cross References to Related Applications
   - Statement Regarding Fed sponsored R & D
   - Reference to Microfiche Appendix
   - Background of the Invention
   - Brief Summary of the Invention
   - Brief Description of the Drawings *(if filed)*
   - Detailed Description
   - Claim(s)
   - Abstract of the Disclosure
3. ☒ Drawing(s) *(35 U.S.C. 113)* [Total Sheets 4]
4. Oath or Declaration [Total Pages 3]
   a. ☐ Newly executed (original copy)
   b. ☐ Copy from a prior application (37 C.F.R. § 1.63(d)) *(for continuation/divisional with Box 16 completed)*
      i. ☐ DELETION OF INVENTOR(S)
      Signed statement attached deleting inventor(s) named in the prior application, see 37 CFR §§ 1.63(d)(2) and 1.33(b).

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6. Nucleotide and/or Amino Acid Sequence Submission *(if applicable, all necessary)*
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ACCOMPANYING APPLICATION PARTS

7. ☐ Assignment Papers (cover sheet & document(s))
8. ☐ 37 C.F.R. § 3.73(b) Statement *(when there is an assignee)* ☐ Power of Attorney
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Prior application Information: Examiner ______ *Group/Art Unit:* ______

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APPLICATION FOR UNITED STATES LETTERS PATENT

FOR

METHOD OF CONVERTING A SUB-SAMPLED COLOR IMAGE

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"Express Mail" label number EL034432552US

METHOD OF CONVERTING A SUB-SAMPLED COLOR IMAGE

RELATED APPLICATION

This patent application is related to concurrently filed U.S. patent application serial no. ___________, titled "Method of Upscaling A Color Image," by Acharya,(attorney docket no. 042390.P7489), assigned to the assignee of the current invention and herein incorporated by reference.

BACKGROUND

This disclosure relates to color conversion and, more particularly, to converting from a sub-sampled color image in a first color space format to a full color image in a second color space format.

As is well-known, in a variety of circumstances, it is a desirable to apply a technique to convert from a sub-sampled color image to a full color image. For example, for a camera or other imager that has the capability of creating a color image, typically it is too expensive to have the capability to capture three independent color pixel signal values for each pixel location of an image of a particular size or dimension. Therefore, more typically, a sub-sampled color image is captured and the missing color pixel signal values at each pixel location are computed using a variety of techniques. In other words, each pixel location may have a single color signal value rather than three independent color signal

values, for example. A need continues to exist for techniques for creating a full color image of good quality from a sub-sampled color image.

BRIEF DESCRIPTION OF DRAWINGS

The subject matter regarded as the invention is particularly pointed out and distinctly claimed in the concluding portion of the specification. The invention, however, both as to organization and method of operation, together with objects, features, and advantages thereof, may best be understood by reference to the following detailed description when read with the accompanying drawings in which:

Fig. 1 is a schematic diagram illustrating a sub-sampled color image, such as a Bayer pattern color image;

Fig. 2 is a schematic diagram illustrating one technique for producing a full color image from a sub-sampled color image and subsequently converting to another color space format;

Fig. 3 is a schematic diagram illustrating a technique of converting from a sub-sampled color image to a full color image in accordance with the present invention; and

Fig. 4 is an alternative way to represent the sub-sampled color image of Fig. 1.

DETAILED DESCRIPTION

In the following detailed description, numerous specific details are set forth in order to provide a thorough understanding of the invention. However, it

will be understood by those skilled in the art that the present invention may be practiced without these specific details. In other instances, well-known methods, procedures, components, and circuits have not been described in detail so as not to obscure the present invention.

As previously indicated, for a color image, typically each pixel signal value is represented by three independent color components, such as a red component, a green component, and a blue component, for example. However, the invention is not limited in scope to these color components or to this particular color space format. Ideally, three image sensors would be used to capture the three color components. However, the use of three sensors in a single image capture device is typically expensive and also may not be suitable for use in low power handheld devices, such as a mobile handset designed to display such color images, for example.

In order to reduce cost, typically the color image is captured in a sub-sampled form using a single sensor in each pixel location with a suitable color filter array (CFA) "on top" of the sensor. Of course, the invention is not limited in scope to use with such an image capture device, however. Nonetheless, in such an approach, each pixel location comprises only one color component signal value, thereby forming a type of sub-sampled color image. For example, in one approach, each pixel signal value may comprise either a red color signal value, a green color signal value, or a blue color signal value represented by eight binary digital signals or bits. Although the invention is not limited in scope in this

respect, one such pattern is a Bayer pattern, as illustrated schematically in Fig. 1.

Of course, for a color image formed using three color sensors in each pixel location, each location would include signal information for all three independent color components. Therefore, typically, for a color image captured by the latter device, each pixel is represented by a 24 bit color signal, 8 bits for each of the red, green, and blue color components, for example. Again, the invention is not restricted in scope by this example; however, in order to produce such an image from a device employing one color sensor in each pixel location, for example, signal interpolation would typically be employed. In one example of signal interpolation, the two missing color components for each pixel location are obtained by using color signal information provided by neighboring pixel signal values.

If a full color image is obtained in this manner, a transformation into a different color space format may then be employed. For example, it may be desirable to comply with certain image processing specifications and/or standards, such as those provided by the International Telecommunications Union (ITU) or the International Standards Organization (ISO), although the invention is not limited in scope in this respect. Likewise, it is also typical to represent color images in a luminance-chrominance (L-C) form in order to reduce the storage requirements by sub-sampling redundant color signal information that may be present in the image, typically in the chrominance color

components. One widely used L-C color space format is the Y-Cr-Cb 4:2:0 representation, although, again, this is just an example.

Disadvantages of current techniques to produce a full color image from a sub-sampled color image include (1) the loss of signal information as a result of applying the particular technique and/or (2) high computational complexity, which also may typically consume excessive power when employed or performed by a computing engine, and/or (3) internal buffering large enough to store the signal information during and after processing. These disadvantages will be explained in more detail hereinafter. An embodiment of converting from a sub-sampled color image to a full color image in accordance with the present invention may avoid these disadvantages.

As is well-known, a color interpolation method or process, such as described in "Method of Interpolating Color Pixel Signals from a Subsampled Color Image," by Acharya et al., filed on October 1, 1999, US patent application serial number 09/410,800,(attorney docket no. 042390.P7331), assigned to the assignee of the present invention, for example, generates a full color digital image comprising three color planes, red, green, and blue, each of size M x N from a Bayer pattern sub-sampled image by generating the missing two color components for each pixel location. Of course, this is just one example of a color interpolation process, and the invention is not limited in scope to this or any other particular approach. There are a wide number of color interpolation techniques that may be employed. Typically, the color signal information of the

neighboring pixels are employed to generate the missing color signal information for each pixel. A simple approach to implement would be to employ the median of the neighboring pixels. Of course, more complex approaches may also be employed. Fig. 2 illustrates a process in which a sub-sampled image is interpolated to produce a full color image.

Subsequently, for the approach illustrated in Fig. 2, an interpolated full color image is converted to a sub-sampled luminance-chrominance (L-C) color space format, such as Y-Cr-Cb 4:2:0, to meet color specifications or criteria, such as provided, for example, in the H.263 ITU standard, applied in video conferencing applications. Of course, the invention is not restricted in scope in this respect. The color space format conversion from 24 bit RGB color space format to 12 bit Y-Cr-Cb 4:2:0 color space format is done using the following transformation:

$$\begin{aligned} Y(I,J) &= 0.299R(I,J) + 0.587G(I,J) + 0.114B(I,J) \\ Cr(I,J) &= -0.169R(I,J) - 0.331G(I,J) + 0.500B(I,J) \\ Cb(I,J) &= 0.500R(I,J) - 0.419G(I,J) - 0.081B(I,J) \end{aligned} \qquad [1]$$

where R,G, and B denote different color planes in the RGB color space format, Y, Cr, and Cb denote different color planes in the Y-Cr-Cb 4:2:0 color space format, and I,J denote pixel locations.

The Cr and Cb image planes are then, in this particular approach, decimated by dropping alternate rows and columns from each chrominance plane (Cb and Cr), as illustrated by Cr' or Cb' in Fig. 2. This generates the Y-Cr-Cb image in 4:2:0 color space (12 bit color) format. The reason for 12 bits for each pixel in Y-Cr-Cb 4:2:0 color space is that for every 4 luminance (Y) pixels (1 byte each for each luminance value) in this format there is 1 value (1 byte each) for each corresponding chrominance channel (Cb and Cr in this example). Hence, 4 full color pixels in this format are represented by 6 bytes or 48 bits. As a result, each pixel in Y-Cr-Cb color space format is considered to have 12 bits.

Assume that the average number of operations to recover each missing color signal value in a particular pixel location is "K", when using a known color interpolation technique. Then, to recover two missing color space components for each pixel location, the total number of operations to restore the full color image using this approach is 2Kx(MxN), where "x" denotes multiplication. The total number of multiplications for color conversion is 9MxN, and the number of additions is 6MxN. Therefore, ignoring the computation for sub-sampling, the typical number of operations for color interpolation followed by color conversion is more than (2K + 15)xMxN. Likewise, the memory buffer size employed for hardware and/or software implementation of this approach is 3MxN.

Fig. 3 illustrates an embodiment in accordance with the present invention. Of course, the invention is not limited in scope to this particular embodiment. In this embodiment, however, a sub-sampled color image in a first color space

format, such as a Bayer pattern in RGB color space, is transformed to a second color space format, such as Y-Cr-Cb color space format. In this particular embodiment, the Bayer pattern of size M x N is converted to an image of size M/2 x N/2 using an integrated approach that avoids computationally complex color interpolation methodologies and the decimation operation previously described. Then, at least one of the color space dimensions in the transformed image is "upscaled" to provide a full color image in a second color space format.

In this context, the term upscaled refers to a process applied to a color plane of a color dimension in a particular color space format whereby the color signal information in the color plane is retained, but spread or distributed over a color plane of larger dimensions. For example, for the embodiment illustrated in Fig 3, the Y plane of size M/2 x N/2 is upscaled using a discrete wavelet transform (DWT) based upsampling technique in order to generate an M x N Y-Cb-Cr 4:2:0 color image. Of course, the invention is not limited in scope to using the discrete wavelet transform and many other sampling techniques may be employed such as bi-linear interpolation, weighted averaging,etc. An advantage of this particular approach is that the chrominance plane is not decimated and, hence, there is no significant loss of signal information as would typically occur.

To illustrate this particular embodiment in greater detail, Fig. 4 is a schematic diagram that represents the Bayer pattern of Fig. 1 differently than in Fig. 1. Each block B(I,J) represents a 2 x 2 Bayer pattern as shown in Fig. 4.

Integrated color interpolation and color space conversion is accomplished using the previous transformation or equations [1] with the following additional relationships applying also:

$$
\begin{aligned}
R(I,J) &= R \\
G(I,J) &= (G1 + G2)/2 \qquad [2] \\
B(I,J) &= B
\end{aligned}
$$

where R, G1, G2, and B are from the block B(I,J).

As a result of this transformation, a Y-Cr-Cb color image of size M/2 x N/2 is obtained because each 2 x 2 Block produces a single pixel signal value in this color space format. The Y plane may then be upsampled to generate the M x N size Y-Cr-Cb 4:2:2 color space format image. One technique for performing this upscaling is described in greater detail in a prior patent application "A DWT-based Up-Sampling Algorithm Suitable For Image Display In An LCD panel," by Acharya, filed on August 5, 1998, US patent application serial no. 09/129,728,(Docket No. 042390.P6080), assigned to the assignee of the present invention, although the invention is not limited in scope in this respect.. As previously indicated any one of a number of techniques to perform the upscaling may be employed.

It is noted that the computational complexity of this approach and the amount of storage space utilized is significantly less than the previous approach.

As discussed above, the total number of multiplications for an integrated color interpolation and color conversion is 9x(M/2)x(N/2) or (9/4)MxN and a similar number of additions and subtractions. Hence, the total number of operations is 4.5 MxN. In this particular embodiment, for an upscaling operation for the Y plane, the computational complexity is similar to that of color interpolation; however, the upscaling is applied to data of size M/2 x N/2. Hence, for upscaling the Y plane, the total number of operations is KxMxN. Hence, the total number of operations for this particular embodiment is (K+4.5)xMxN, which is less than half of the approach previously described in terms of computational complexity. Likewise, the storage space employed to implement this approach is 1.5MxN or about half of the approach previously described.

As previously indicated, an embodiment of a method of converting from a sub-sampled color image in a first color space format to a full color image in a second color space format in accordance with the invention provides a number of advantages. The color interpolation approach is integrated with the color conversion methodology. As a result, a computationally complex color interpolation scheme is avoided totally with the trade off being the addition of an upscaling scheme applied to a reduced set of data. Because of this integrated approach, pipelining the imaging processing flow, as is desirable in implementing video, for example, is relative straightforward and useful for such applications. The reduction in computational complexity is more than 50%, and in memory storage space is about 50%. Therefore, this approach may be applied to

virtually any digital signal processing architecture or similar computing engine and may reduce computational complexities suitable for real-time application and low power applications, such as may be desirable for handheld devices, with generally no significant loss of signal information.

It will, of course, be understood that, although a particular embodiment has just been described, the invention is not limited in scope to a particular embodiment or implementation. For example, one embodiment may be in hardware, whereas another embodiment may be in software. Likewise, an embodiment may be in firmware, or any combination of hardware, software, or firmware, for example. Likewise, although the invention is not limited in scope in this respect, one embodiment may comprise an article, such as a storage medium. Such a storage medium, such as, for example, a CD-ROM, or a disk, may have stored thereon instructions, which when executed by a system, such as a computer system or platform, or an imaging system, may result in a method of upscaling a color image in accordance with the invention, such as, for example, the embodiment previously described.

While certain features of the invention have been illustrated and described herein, many modifications, substitutions, changes and equivalents will now occur to those skilled in the art. It is, therefore, to be understood that the appended claims are intended to cover all such modifications and changes as fall within the true spirit of the invention.

Claims:

1. A method of converting from a sub-sampled color image in a first color space format to a full color image in a second color space format comprising:

transforming the sub-sampled color image in the first color space format to the second color space format; and

upscaling at least one color plane of the transformed image, the one color plane corresponding to one of the color space dimensions of the second color space format, to provide the full color image in the second color space format.

2. The method of claim 1, wherein the first color space format is the RGB color space format.

3. The method of claim 2, wherein the second color space format is the Y-Cr-Cb 4:2:0 color space format.

4. The method of claim 1, wherein the first and second color space formats comprise two different luminance-chrominance color space formats.

5. The method of claim 1, wherein transforming comprises applying a relationship to at least one pixel value of the image in the first color space format to obtain a pixel value in the second color space format.

6. The method of claim 5, wherein transforming comprises applying the relationship to more than at least one pixel value of the image in the first color space format.

7. The method of claim 5, wherein the relationship is substantially in accordance with the following equations:

$$Y(I,J) = 0.299R(I,J) + 0.587G(I,J) + 0.114B(I,J)$$

$$Cr(I,J) = -0.169R(I,J) - 0.331G(I,J) + 0.500B(I,J)$$

$$Cb(I,J) = 0.500R(I,J) - 0.419G(I,J) - 0.081B(I,J)$$

where R,G, and B denote different color planes in the RGB color space format, Y, Cr, and Cb denote different color planes in the Y-Cr-Cb 4:2:0 color space format, and I,J denote pixel locations.

8. The method of claim 1, wherein upscaling comprises applying an Inverse discrete wavelet transform to an image decomposed into subbands, at least one of the subbands comprising the at least one color plane of the transformed image.

9. The method of claim 8, wherein the at least one of the subbands comprises an LL subband of the decomposed image.

10. The method of claim 9, wherein the remaining subbands of the decomposed image comprise only zeros.

11. An article comprising: a storage medium having stored thereon instructions to convert from a sub-sampled color image in a first color space format to a full color image in a second color space format, the instructions, when executed by a system, resulting in:

transforming the sub-sampled color image in the first color space format to the second color space format; and

upscaling at least one color plane of the transformed image, the one color plane corresponding to one of the color space dimensions of the second color space format, to provide the full color image in the second color space format.

12. The article of claim 11, wherein the first color space format is the RGB color space format.

13. The article of claim 12, wherein the second color space format is the Y-Cr-Cb 4:2:0 color space format.

14. The article of claim 11, wherein the first and second color space formats comprise two different luminance-chrominance color space formats.

15. The article of claim 11, wherein the instructions, when executed, further result in transforming the color image comprising applying a relationship to at least one pixel value of the image in the first color space format to obtain a pixel value in the second color space format.

16. The article of claim 15, wherein the instructions, when executed, further result in the relationship being applied substantially in accordance with the following equations:

$$Y(I,J) = 0.299R(I,J) + 0.587G(I,J) + 0.114B(I,J)$$

$$Cr(I,J) = -0.169R(I,J) - 0.331G(I,J) + 0.500B(I,J)$$

$$Cb(I,J) = 0.500R(I,J) - 0.419G(I,J) - 0.081B(I,J)$$

where R,G, and B denote different color planes in the RGB color space format, Y, Cr, and Cb denote different color planes in the Y-Cr-Cb 4:2:0 color space format, and I,J denote pixel locations.

17. The article of claim 11, wherein the instructions, when executed, further result in upscaling at least one color plane comprising applying an Inverse discrete wavelet transform to an image decomposed into subbands, at least one of the subbands comprising the at least one color plane of the transformed image.

18. The article of claim 17, wherein the instructions, when executed, further result in the at least one of the subbands comprising an LL subband of the decomposed image.

19. The article of claim 18, wherein the instructions, when executed, further result in the remaining subbands of the decomposed image comprise only zeros.

20. A method of converting a subsampled color image transformed to a selected color space fomat to a full color image in the selected color space format comprising:

appending zero subbands to at least one of the color planes of the transformed color image so that the at least one of the color planes forms an LL subband of a decomposed image and the appended subbands form LH, HL, and LL subbands of a decomposed image; and

applying the inverse discrete wavelet transform to the decomposed image so as to form the full color image in the selected color space format.

21. The method of claim 20, wherein the selected color space format comprises the Y-Cr-Cb 4:2:0 color space format.

Abstract

A method of converting from a sub-sampled color image in a first color space format to a full color image in a second color space format includes the following. A sub-sampled color image in a first color space format is transformed to a second color space format. At least one color plane of the transformed image is upscaled, the one color plane corresponding to one of the color space dimensions of the second color space format, to provide the full color image in the second color space format. Of course, many other embodiments other than the preceding embodiment are also within the scope of the present invention.

R	G1	R	G1	R	G1	R	G1	...	...
G2	B	G2	B	G2	B	G2	B	...	...
R	G1	R	G1	R	G1	R	G1	...	...
G2	B	G2	B	G2	B	G2	B	...	...
R	G1	R	G1	R	G1	R	G1	...	...
G2	B	G2	B	G2	B	G2	B	...	...
R	G1	R	G1	R	G1	R	G1	...	...
G2	B	G2	B	G2	B	G2	B	...	...
:	:	:	:	:	:	:	:	...	...
:	:	:	:	:	:	:	:	...	...

Figure 1: Bayer Pattern

P7490

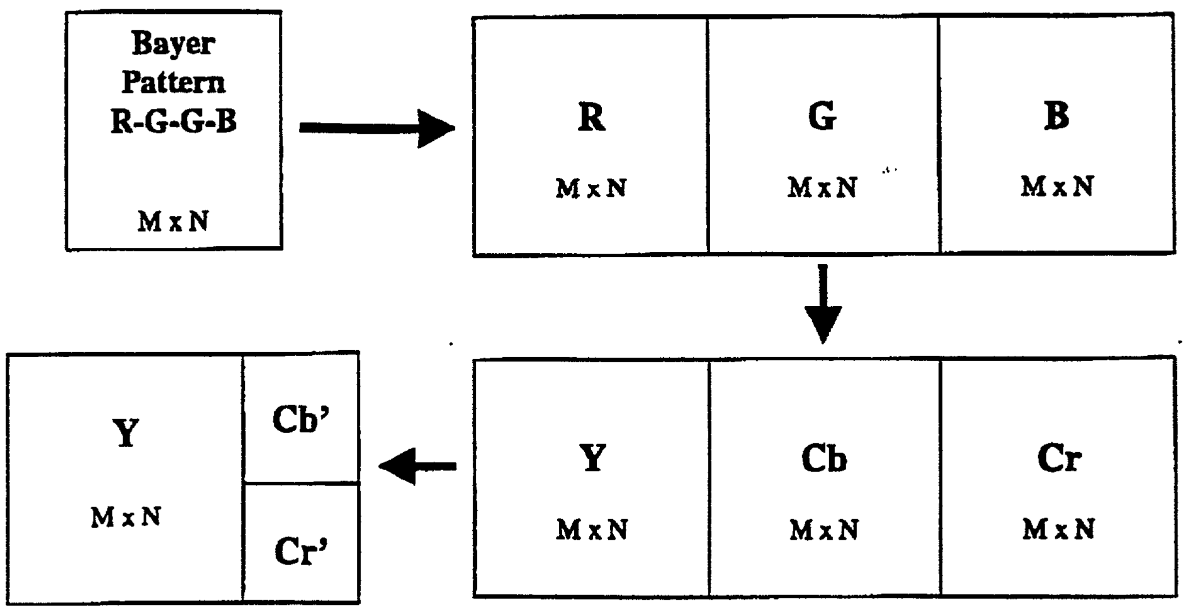

Figure 2

P7490

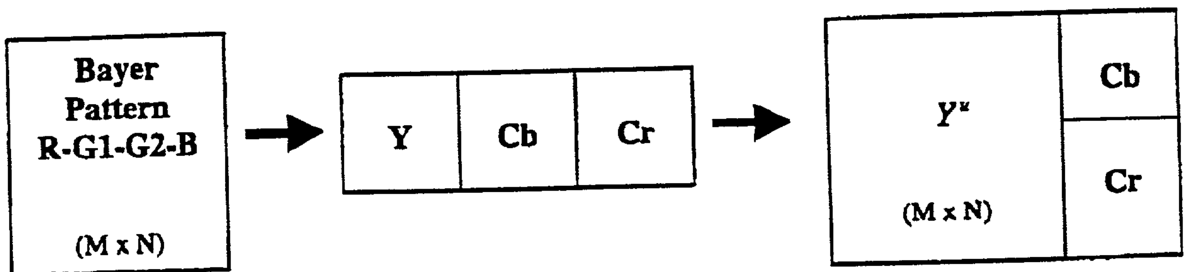

Figure 3

P7490

B(0,0)	B(0,1)	B(0,2)	B(0,3)	.....
B(1,0)	B(1,1)	B(1,2)	B(1,3)	.....
B(2,0)	B(2,1)	B(2,2)	B(2,3)	.....
B(3,0)	B(3,1)	B(3,2)	B(3,3)	.....
: :	: :	: :	: :	.....

B(m,n) =

R	G1
G2	B

Figure 4

P7490

DECLARATION AND POWER OF ATTORNEY FOR PATENT APPLICATION (FOR INTEL CORPORATION PATENT APPLICATIONS)

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below, next to my name.

I believe I am the original, first, and sole inventor (if only one name is listed below) or an original, first, and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled

METHOD OF CONVERTING A SUB-SAMPLED COLOR IMAGE

the specification of which

[X] is attached hereto.
[ ] was filed on ______________ as
United States Application Number ______________
or PCT International Application Number ______________
and was amended on ______________.
(if applicable)

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claim(s), as amended by any amendment referred to above. I do not know and do not believe that the claimed invention was ever known or used in the United States of America before my invention thereof, or patented or described in any printed publication in any country before my invention thereof or more than one year prior to this application, that the same was not in public use or on sale in the United States of America more than one year prior to this application, and that the invention has not been patented or made the subject of an inventor's certificate issued before the date of this application in any country foreign to the United States of America on an application filed by me or my legal representatives or assigns more than twelve months (for a utility patent application) or six months (for a design patent application) prior to this application.

I acknowledge the duty to disclose all information known to me to be material to patentability as defined in Title 37, Code of Federal Regulations, Section 1.56.

I hereby claim foreign priority benefits under Title 35, United States Code, Section 119(a)-(d), of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

Prior Foreign Application(s):

APPLICATION NUMBER	COUNTRY (OR INDICATE IF PCT)	DATE OF FILING (day, **month**, year)	PRIORITY CLAIMED UNDER 37 USC 119
			[ ] No [ ] Yes
			[ ] No [ ] Yes
			[ ] No [ ] Yes

I hereby claim the benefit under Title 35, United States Code, Section 119(e) of any United States provisional application(s) listed below:

APPLICATION NUMBER	FILING DATE

I hereby claim the benefit under Title 35, United States Code, Section 120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code, Section 112, I acknowledge the duty to disclose all information known to me to be material to patentability as defined in Title 37, Code of Federal Regulations, Section 1.56 which became available between the filing date of the prior application and the national or PCT international filing date of this application:

APPLICATION NUMBER	FILING DATE	STATUS (ISSUED, PENDING, ABANDONED)

I hereby appoint BLAKELY, SOKOLOFF, TAYLOR & ZAFMAN LLP, a firm including: William E. Alford, Reg. No. 37,764; Farzad E. Amini, Reg. No. P42,261; Aloysius T. C. AuYeung, Reg. No. 35,432; William Thomas Babbitt, Reg. No. 39,591; Carol F. Barry, Reg. No. 41,600; Jordan Michael Becker, Reg. No. 39,602; Bradley J. Bereznak, Reg. No. 33,474; Michael A. Bernadicou, Reg. No. 35,934; Roger W. Blakely, Jr., Reg. No. 25,831; Gregory D. Caldwell, Reg. No. 39,926; Ronald C. Card, Reg. No. 44,587; Thomas M. Coester, Reg. No. 39,637; Stephen M. De Klerk, under 37 C.F.R. § 10.9(b); Michael Anthony DeSanctis, Reg. No. 39,957; Daniel M. De Vos, Reg. No. 37,813; Robert Andrew Diehl, Reg. No. 40,992; Matthew C. Fagan, Reg. No. 37,542; Tarek N. Fahmi, Reg. No. 41,402; James Y. Go, Reg. No. 40,621; James A. Henry, Reg. No. 41,064; Willmore F. Holbrow III, Reg. No. P41,845; Sheryl Sue Holloway, Reg. No. 37,850; George W Hoover II, Reg. No. 32,992; Eric S. Hyman, Reg. No. 30,139; Dag H. Johansen, Reg. No. 36,172; William W. Kidd, Reg. No. 31,772; Erica W. Kuo, Reg. No. 42,775; Michael J. Mallie, Reg. No. 36,591; Andre L. Marais, under 37 C.F.R. § 10.9(b); Paul A. Mendonsa, Reg. No. 42,879; Darren J. Milliken, Reg. 42,004; Lisa A. Norris, Reg. No. P44,976; Chun M. Ng, Reg. No. 36,878; Thien T. Nguyen, Reg. No. 43,835; Thinh V. Nguyen, Reg. No. 42,034; Dennis A. Nicholls, Reg. No. 42,036; Kimberley G. Nobles, Reg. No. 38,255; Daniel E. Ovanezian, Reg. No. 41,236; Babak Redjaian, Reg. No. 42,096; William F. Ryann, Reg. 44,313; James H. Salter, Reg. No. 35,668; William W. Schaal, Reg. No. 39,018; James C. Scheller, Reg. No. 31,195; Jeffrey Sam Smith, Reg. No. 39,377; Maria McCormack Sobrino, Reg. No. 31,639; Stanley W. Sokoloff, Reg. No. 25,128; Judith A. Szepesi, Reg. No. 39,393; Vincent P. Tassinari, Reg. No. 42,179; Edwin H. Taylor, Reg. No. 25,129; John F. Travis, Reg. No. 43,203; George G. C. Tseng, Reg. No. 41,355; Joseph A. Twarowski, Reg. No. 42,191; Lester J. Vincent, Reg. No. 31,460; Glenn E. Von Tersch, Reg. No. 41,364; John Patrick Ward, Reg. No. 40,216; Charles T. J. Weigell, Reg. No. 43,398; Kirk D. Williams, Reg. No. 42,229; James M. Wu, Reg. No. P45,241; Steven D. Yates, Reg. No. 42,242; Ben J. Yorks, Reg. No. 33,609; and Norman Zafman, Reg. No. 26,250; my patent attorneys, and Andrew C. Chen, Reg. No. 43,544; Justin M. Dillon, Reg. No. 42,486; Paramita Ghosh, Reg. No. 42,806; and Sang Hui Kim, Reg. No. 40,450; my patent agents, of BLAKELY, SOKOLOFF, TAYLOR & ZAFMAN LLP, with offices located at 12400 Wilshire Boulevard, 7th Floor, Los Angeles, California 90025, telephone (310) 207-3800, and Alan K. Aldous, Reg. No. 31,905; Robert D. Anderson, Reg. No. 33,826; Joseph R. Bond, Reg. No. 36,458; Richard C. Calderwood, Reg. No. 35,468; Jeffrey S. Draeger, Reg. No. 41,000; Cynthia Thomas Faatz, Reg No. 39,973; Sean Fitzgerald, Reg. No. 32,027; Seth Z. Kalson, Reg. No. 40,670; David J. Kaplan, Reg. No. 41,105; Charles A. Mirho, Reg. No. 41,199; Leo V. Novakoski, Reg. No. 37,198; Naomi Obinata, Reg. No. 39,320; Thomas C. Reynolds, Reg. No. 32,488; Kenneth M. Seddon, Reg. No. 43,105; Mark Seeley, Reg. No. 32,299; Steven P. Skabrat, Reg. No. 36,279; Howard A. Skaist, Reg. No. 36,008; Steven C. Stewart, Reg. No. 33,555; Raymond J. Werner, Reg. No. 34,752; Robert G. Winkle, Reg. No. 37,474; and Charles K. Young, Reg. No. 39,435; my patent attorneys, and Thomas Raleigh Lane, Reg. No. 42,781; Calvin E. Wells; Reg. No. P43,256, Peter Lam, Reg. No. P44,855; and Gene I. Su, Reg. No. 45,140; my patent agents, of INTEL CORPORATION; and James R. Thein, Reg. No. 31,710, my patent attorney; with full power of substitution and revocation, to prosecute this application and to transact all business in the Patent and Trademark Office connected herewith.

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I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

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